# Effect of Cropping Frequency on Grain Yields, N Balance and Economic Returns for Properly Fertilized Spring Wheat in Southwestern Saskatchewan

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**Introduction**
Producers in the semiarid Brown soil zone have traditionally used cropping systems that include high proportions of summerfallow to conserve water, control weeds, and increase available N. In recent years, however, many producers have begun to extend their rotations, some moving all the way to continuous cropping.

This paper examines the influence of changes in cropping frequency on grain yields and quality, N balance in the soil-plant system, and economic returns from spring wheat production on a medium texture soil at Swift Current, SK. We compared the effects of moving from a 2-yr fallow-wheat (F-W) system, to a 3-yr F-W-W rotation, to a 6-yr F-W-W-W-W-W rotation, and finally to a continuous wheat rotation. The analysis draws on 18 years of data (1985-2002) from a long-term crop rotation experiment being conducted at the Semiarid Prairie Agricultural Research Centre.

**Materials and Methods**
The experiment was initiated in 1967 on a Swinton loam involving 12 rotation systems, of which we selected 4 rotations for evaluation. The 6-yr F-W-W-W-W-W rotation was constructed in 1985 from flax-wheat-wheat and oat hay-wheat-wheat rotations that existed from 1967 to 1984.

All phases of each rotation are present every year and each rotation was cycled on its assigned plots. Plots were 10 m x 40 m in size, arranged in a randomized complete block design with 3 replicates.

Tillage was kept to a minimum to conserve surface crop residues. Areas being cropped received one tillage operation in spring using a heavy-duty cultivator with mounted harrows to prepare the seedbed. Fallow areas received an average of 4 tillage operations during the 21-month fallow period. There was no post-harvest tillage performed on cropped areas, but all plots received 2,4-D each fall for control of winter annual weeds.

Wheat received recommended rates of N and P fertilizer based on $NO_3$-N levels in the 0-60 cm depth of soil, measured on a per plot basis the previous fall. Wheat grown on fallow received an average of 7 kg N ha$^{-1}$ from 1985-90, and since 1991, received 34 kg N ha$^{-1}$ due to the more favorable weather conditions and a change in fertilizer recommendation guidelines (Table 1). Wheat grown on stubble received an average of 21 kg N ha$^{-1}$ from 1985-90 and 52 kg N ha$^{-1}$ thereafter. All wheat plots received an average of 22 kg $P_2O_5$ ha$^{-1}$. The N was broadcast prior to seedbed preparation and the P was seed placed.

All wheat crops received in-crop herbicides using recommended rates of bromoxynil plus MCPA E (1:1) and tralkoxydim, applied alone or in combination as required.

Grain protein concentration (%N x 5.7) was corrected to a constant 13.5% moisture basis.

The economic analysis used 2003 cost levels for all inputs. Wheat was valued at a base price of \$151 t$^{-1}$ (12% protein content), with the price adjusted based on grain protein concentration using the 2003-04 protein price schedule established by the Canadian Wheat Board. Participation in the Canada/Saskatchewan Crop Insurance program was assumed to be at 70% yield coverage. Premium rates and payout criteria for Risk Area #10 were assumed.

**Table 1.** Rates of N fertilizer applied (kg ha$^{-1}$).

| **Rotation** | **1985-1990** | **1991-2002** | **Mean** |
|---|---|---|---|
| **Fallow** | | | |
| F-(**W**) | 7 | 38 | 28 |
| F-(**W**)-W | 8 | 34 | 25 |
| F-(**W**)-W-W-W-W | 7 | 30 | 22 |
| **Stubble** | | | |
| F-W-(**W**) | 28 | 55 | 46 |
| F-W-(**W**)-W-W-W | 14 | 46 | 35 |
| F-W-W-(**W**)-W-W | 19 | 52 | 41 |
| F-W-W-W-(**W**)-W | 17 | 53 | 41 |
| F-W-W-W-W-(**W**) | 24 | 52 | 43 |
| Cont. **W** | 24 | 52 | 43 |

## Results and Discussion

### Weather Conditions

- Of the 18 years, there were only 3 years with severe drought (1985, 1988, and 2001), while there were 5 years with well-above average growing conditions (1991, 1993, 1995, 1999, and 2002) (Table 2).
- Growing season (May-August) precipitation was greater than 220 mm in 9 of 18 years, near the long-term mean of 210 mm in 5 years, and less than 190 mm in 4 of 18 years.
- This contrasts with the pervious 18-year period when growing season precipitation was 31% less, averaging only 176 mm, and there were 10 years with well-below average precipitation.

**Table 2.** Average Monthly Precipitation (mm) received during the Growing Season.

| Month | 1985-1990 | 1991-2002 | 1985-2002 | Long-term mean |
|---|---|---|---|---|
| May | 54 | 49 | 51 | 44 |
| June | 58 | 85 | 76 | 72 |
| July | 45 | 61 | 56 | 52 |
| August | 37 | 53 | 47 | 42 |
| Total | 194 | 248 | 230 | 210 |

[1] 106 years.

**Grain Yields and Total Wheat Production**

- Grain yields were above-average for the Brown soil zone during this 18-yr period (Fig. 1), primarily reflecting the above-average growing season precipitation that prevailed throughout much of the 1990s and the increased rates of N fertilizer applied since 1991.
- Wheat grown on fallow yielded 2635 kg ha$^{-1}$ over the 1985-2002 period, while wheat grown on stubble yielded 1832 kg ha$^{-1}$, for an average stubble/fallow yield ratio of 70%.
- Yields of wheat grown on fallow and on stubble were unaffected by cropping frequency (Table 3), reflecting the lack of difference in stored soil water as affected by cropping frequency. Spring soil water reserves in the 0-120 cm depth for fallow systems averaged 250 mm, while in stubble systems it averaged 201 mm.
- Water use efficiency averaged 6.55 kg ha$^{-1}$ mm$^{-1}$ for wheat grown on fallow and 5.10 kg ha$^{-1}$ mm$^{-1}$ for wheat grown on stubble.
- In contrast to the rotation-phase yields, total grain production for the complete rotation systems varied directly with cropping frequency (Table 4). The F-W-W rotation produced 16% more grain than F-W, while F-W-W-W-W produced 29% more, and Cont W produced 42% more grain than F-W.

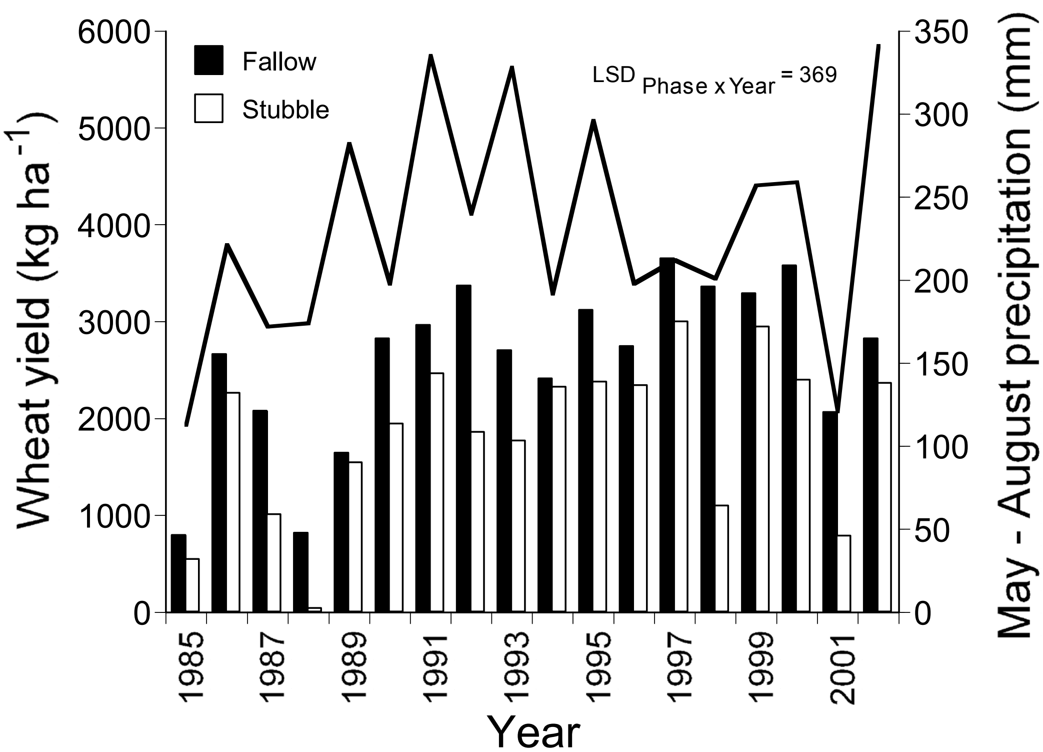


**Figure 1.** Yield of wheat grown on fallow and stubble at Swift Current, SK (1985-2002).

**Table 3.** Average Wheat Yields (kg ha$^{-1}$) by Phase of Rotation.

| Rotation | 1985-1990 | 1991-2002 | Mean | % of F-(W) |
|---|---|---|---|---|
| **Fallow** | | | | |
| F-(**W**) | 1835 | 2922 | 2579 | 100 |
| F-(**W**)-W | 1854 | 3031 | 2658 | 103 |
| F-(**W**)-W-W-W-W | 1893[1] | 2962 | 2668 | 103 |
| **Stubble** | | | | |
| F-W-(**W**) | 1336 | 2071 | 1839 | 71 |
| F-W-(**W**)-W-W-W | 1213 | 2079 | 1803 | 70 |
| F-W-W-(**W**)-W-W | 1175 | 2054 | 1774 | 69 |
| F-W-W-W-(**W**)-W | 1230 | 2159 | 1863 | 72 |
| F-W-W-W-W-(**W**) | 1156 | 2227 | 1883 | 73 |
| Cont. **W** | 1212 | 2124 | 1833 | 71 |

[1] Excludes values for 1985 since the wheat was actually planted on stubble.

**Table 4.** Total Annual Grain Production (kg ha$^{-1}$) for Complete Rotation Systems.

| Rotation | 1985-1990 | 1991-2002 | Mean | % of F-W |
|---|---|---|---|---|
| F-W | 917 | 1461 | 1290 | 100 |
| F-W-W | 1063 | 1700 | 1499 | 116 |
| F-W-W-W-W-W | 1081 | 1914 | 1665 | 129 |
| Cont W | 1212 | 2124 | 1833 | 142 |

## N Concentration in Grain and Straw and Overall N Balance

- Grain protein content (%N x 5.7) varied with years (Fig. 2), being higher in drier years (i.e., directly related to water deficit), but was little affected by cropping frequency. Further, there was no significant difference in grain protein content between wheat grown on fallow (average 15.6%) and wheat grown on stubble (average 15.3%).
- N concentration in the straw averaged 4.4 g kg$^{-1}$ for wheat grown on fallow and on stubble, with no consistent effect of cropping frequency.
- A partial N balance indicated that more N was being exported in the grain than was being added as fertilizer, and that this N removal was in inverse proportion to cropping frequency (Table 5).

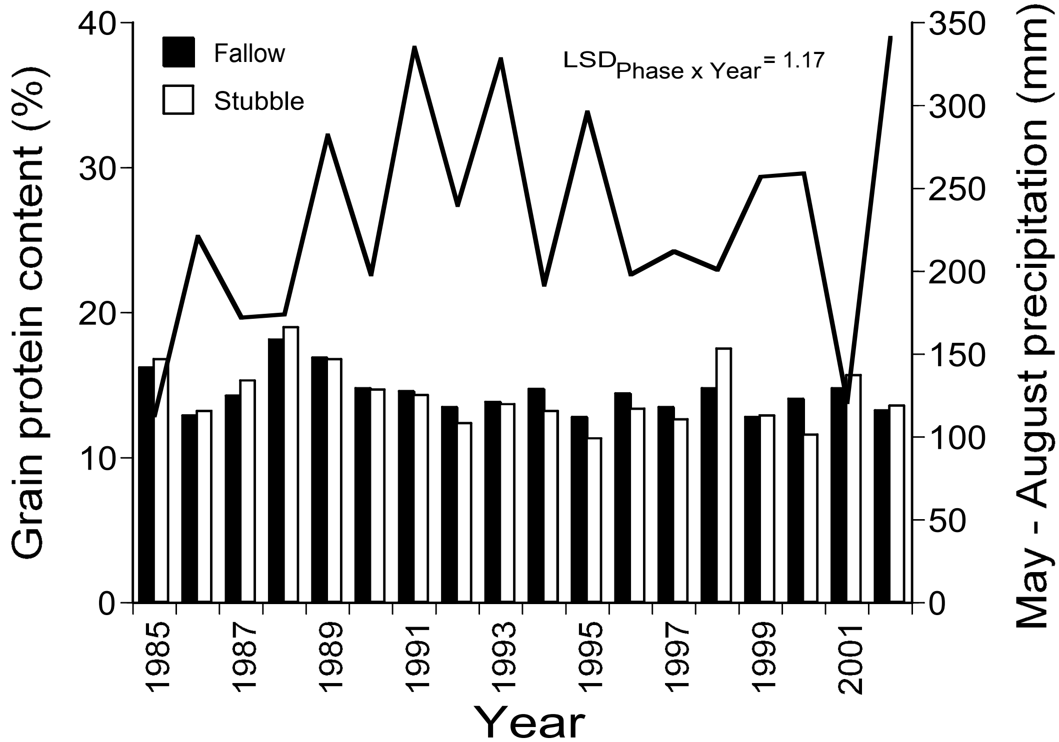


**Figure 2.** Grain protein content of wheat grown on fallow and stubble at Swift Current, SK (1985-2002).

**Table 5.** Partial N Balance (kg ha$^{-1}$) for Cropping Systems (1985-2002).

| Rotation | N applied to all crops | N removed in grain | N lost by erosion[1] | Difference between N applied and removed |
|---|---|---|---|---|
| F-W | 252 | 615 | 108 | -471 |
| F-W-W | 426 | 700 | 90 | -364 |
| F-W-W-W-W-W | 546 | 787 | 53 | -294 |
| Cont W | 774 | 850 | 27 | -103 |

[1] Estimated using the EPIC model.

## Production Costs and Net Returns

- Costs of production (expressed per unit of land area for the complete rotations) increased with cropping frequency, averaging 19% higher (or \$34 ha$^{-1}$ more) for F-W-W than for F-W, 35% higher (or \$64 ha$^{-1}$ more) for F-W-W-W-W-W, and 56% higher (or \$102 ha$^{-1}$ more) for Cont W than for F-W (Table 6).
- The cost of producing a unit of wheat averaged between \$142 and \$155 t$^{-1}$, being lowest for F-W and highest for Cont W. These 'breakeven' values represent the minimum wheat price needed to recover all production costs (except land investment).

**Table 6.** Costs of Production by Crop Rotation (1985-2002)[1].

| Rotation | Mean | Minimum | Maximum | % of F-W | Unit cost |
|---|---|---|---|---|---|
| | ---------------($ ha$^{-1}$)--------------- | | | | ----($ t$^{-1}$)---- |
| F-W | 181 | 152 | 214 | 100 | 142 |
| F-W-W | 215 | 176 | 254 | 119 | 145 |
| F-W-W-W-W-W | 245 | 198 | 294 | 135 | 148 |
| Cont W | 283 | 224 | 352 | 156 | 155 |

[1] Costs do not include land investment.

- Average net returns over the 18-year period (total revenue minus production costs) were statistically similar for all rotation systems at the base wheat price level (Table 7), but they varied greatly among years (Fig. 3).
- On an annual basis, F-W was among the 'group of most profitable rotations' in 9 of 18 years (mainly the drier years), while F-W-W, F-W-W-W-W-W, and Cont W were each among the group of most profitable rotations in 7 of 18 years (generally the wetter years) (Fig 3).
- Increases in the price for wheat enhanced the relative profitability of the more intensive cropping systems (Cont W and F-W-W-W-W-W) because of the greater quantities of wheat produced with these rotations, while decreases in the price for wheat favored the less intensive cropping systems (F-W and F-W-W) (Fig 4).
- Income variability (or riskiness) increased with cropping frequency, being lowest for F-W and highest for Cont W (Fig 5). All risk crop insurance was very effective in reducing (but not eliminating) the increased risk associated with the more intensive cropping systems.

**Table 7.** Net Returns ($ ha$^{-1}$) by Crop Rotation (1985-2002).

| Rotation | Mean | Minimum | Maximum | % of F-W |
|---|---|---|---|---|
| F-W | 45 | -32 | 118 | 100 |
| F-W-W | 48 | -42 | 119 | 107 |
| F-W-W-W-W-W | 51 | -50 | 160 | 113 |
| Cont W | 44 | -76 | 266 | 98 |

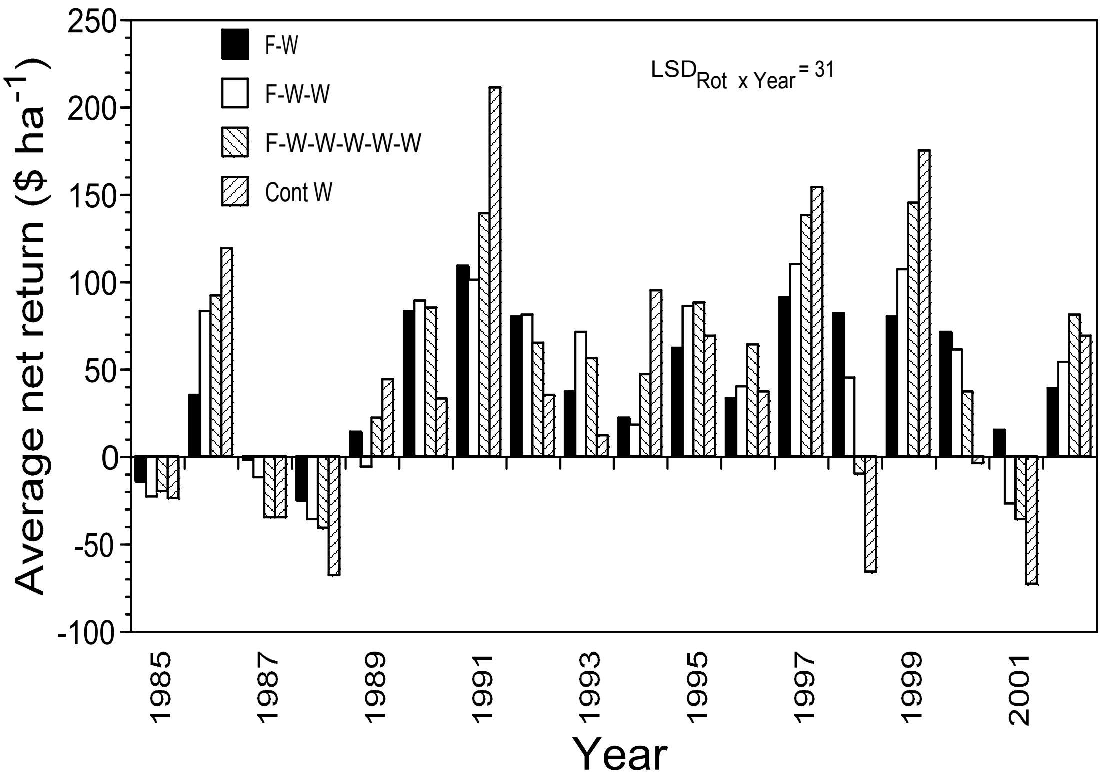


**Figure 3.** Average annual net returns for complete crop rotations (1985-2002).

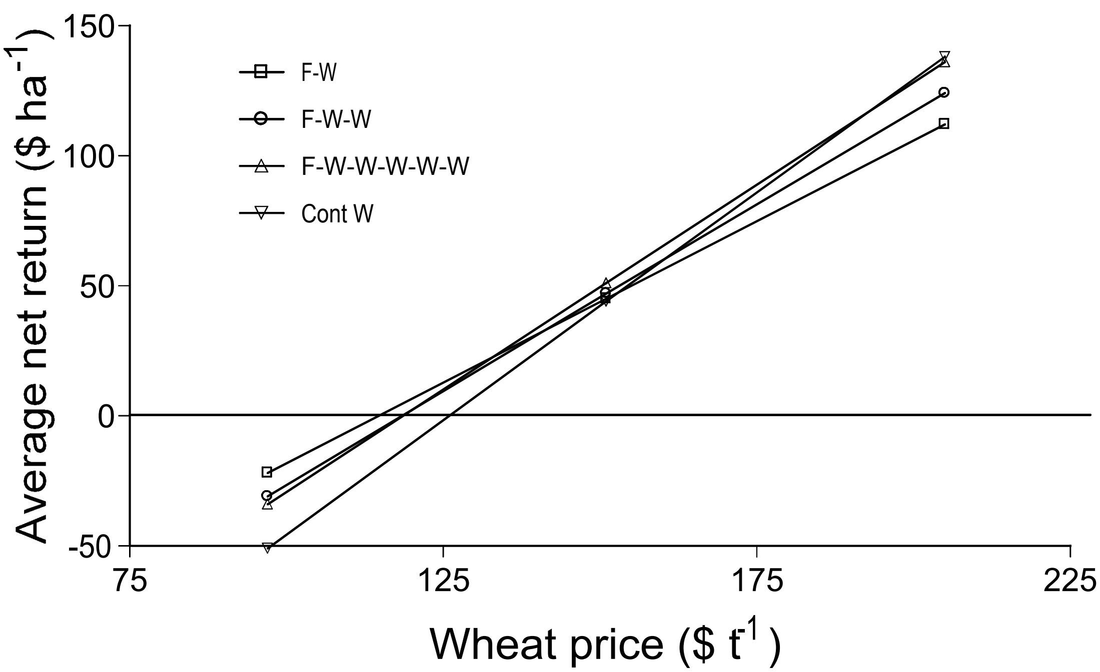


**Figure 4.** Effect of wheat price on average net returns of rotation systems.

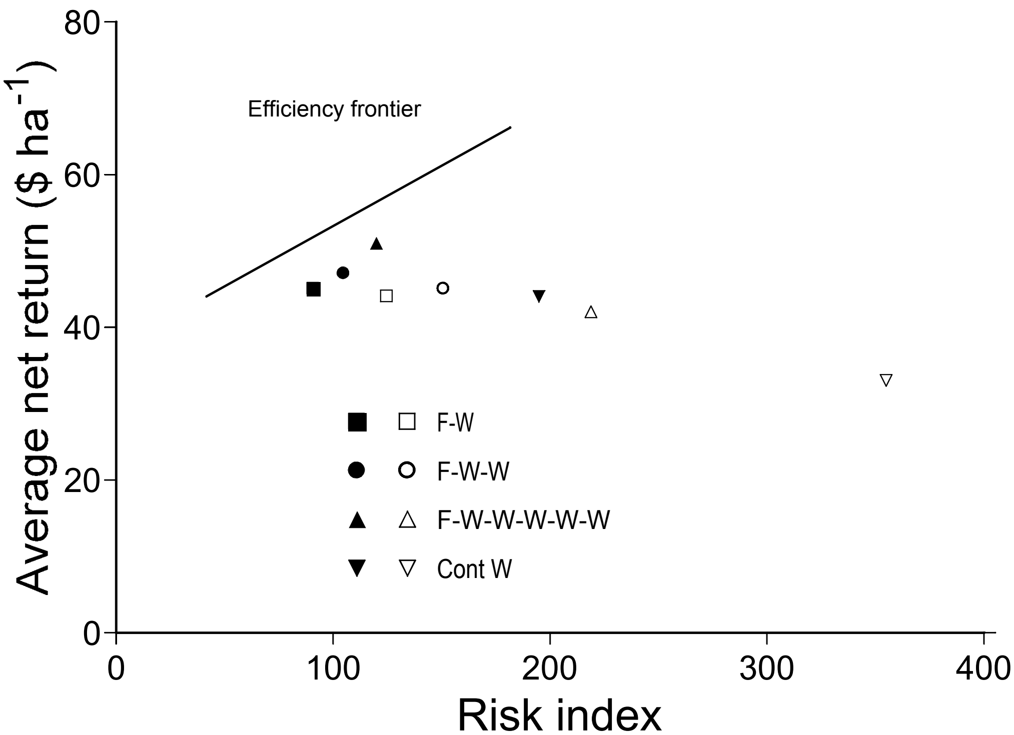


**Figure 5.** Tradeoff between net returns and riskiness for cropping systems, with all-risk crop insurance (closed symbols) and without all-risk crop insurance (open symbols).

**Conclusions**

Our results show that producers wanting to intensify their cropping frequency can do so without experiencing lower wheat yields or lower grain protein, providing soil test rates of fertilizer N and P are applied. In fact, total grain production may increase by as much as 42% when moving from F-W to a Cont W rotation. By cropping the land more intensively and applying recommended rates of fertilizer, producers will also be approaching a more sustainable N balance in their soils. Under the generally favorable growing conditions of the past 18 years and the current price levels for wheat, most producers would do best economically with the 6-yr F-W-W-W-W-W rotation (with all-risk crop insurance) because it provides the highest net return, despite having higher production costs and somewhat greater financial risk compared to the more traditional F-W and F-W-W systems.